Energy Audit Report and Recommendations: Campus Case Study

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Abstract— Energy Auditing in academic institution has the opportunities to improve the energy efficiency of the campus. Reduction of energy consumption, maintaining human comfort, health and safety issues are of primary concern. An energy audit is a study of plant/organization or institute to determine the efficient use of energy. The report accounts for the energy consumption patterns of the academic area, central facilities and hostels based on actual survey and detailed analysis during the audit. The work of auditing encompasses the area wise, application wise and equipment wise consumption traced using suitable auditing equipment. The paper compiles a list of possible actions to conserve and efficiently access the available scarce resources and their saving potential is also identified. This study recommends the change in human behaviour towards optimization that the authorities, students and staff would follow the recommendations in the best possible way.

Key words: Energy Audit, Energy Conservation, Pay-Back Period

I. INTRODUCTION

An energy audit is a survey, inspection and analysis of energy flow for energy conservation in an industry, to reduce the amount of energy input in the system without affecting its output. Energy audit is a testing and analysis of the enterprise, organization for the usage of energy. According to national energy conservation laws and regulations for energy, consumption investigation and energy audit management. [1]

The energy auditing is one of the first tasks to be promoted in the accomplishment of an effective energy cost control program. It consists of a detailed examination of a how the facilities are using energy, and cost of the energy paid for that energy, and a finally, a recommended program for changes in operating practices/energy consumption. With new technology and alternative energy resources now available, this country could possibly reduce its energy consumption by 50%. If there were no barrier to implement [2], but off course there are barriers of cost involved in changes and its pay-back period.

It is the survey of the energy consumption processing/supply aspects related with that industry/ organization. Purpose of energy auditing is to recommend steps to be taken by management for improving the energy efficiency, reduce energy cost and saving the cost on energy bills.

As per energy conservation Act, 2001, Energy Audit is defined as “the verification, monitoring and analysis of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and inaction plan to reduce energy consumption”.[3]

II. OBJECTIVE OF ENERGY AUDIT

The objective of energy audit is to promote the idea of energy conservation in the campus of Guru Nanak Dev Engineering College (GNDEC), Ludhiana, Punjab,

India and to identify, describe and prioritize cost saving measures relating to energy used in the hostels, departments and institute central facilities.

The work eligible for Energy Audit study should be directed towards:

– Identification of areas of energy wastage and estimation of energy saving potential in hostels, departments and institute central facilities.
– Suggesting the cost-effective measures to improve the efficiency to save energy used.
– Estimation of implementation of costs and pay-back periods for each recommended action.
– Documentation of the results and vital information generated through these activities.
– Identification of possible usages of co-generation, renewable (Solar Energy) sources of energy and recommendations for implementation, wherever possible, with cost benefit analysis.

III. ANALYSIS OF AREA USED

Identifying of more energy consumed area, institute area is focused for auditing and raises awareness of energy use and cost. The results of the analysis are used for the review of management and procedures for controlling energy use.
Important points considered for data collection

A. Usage

The use of the equipment in terms of hours per day and days per year is collected from key persons in hostels, departments etc. and ensure the accuracy of this data because much of the potential for energy savings lies on allocation of the equipment’s operating hours.

B. Energy Consumption

Energy/power consumption is measured in actual by energy meter/wattmeter.

C. Supplementary Information

Other information is also collected such as room insulation in case of ACs and availability of natural light etc.

IV. IDENTIFICATION OF TARGET AREAS

Opportunities for energy savings ranges from the simplest, such as lighting retrofits, to the complex, such as the installation of a cogeneration plant. After the preliminary identification of opportunities, more time should be spent on calculation of cost, on those changes, which have shorter payback periods.

V. COST BENEFIT ANALYSIS

The identified energy conservation opportunities should be analyzed in terms of the costs of implementing the project versus the benefits that can be gained. For example, to install a heat plate exchanger to recover wastage of heat, calculate the total cost of installation and compare that with the savings derived from recovering waste heat.

VI. ACTION PLAN PRIORITY

To compute the cost benefit test, the action plan has been developed to ensure that the opportunities identified are implemented. This includes all the major steps for implementing the opportunity as well as the people using the equipment. Furthermore, there is a plan for monitoring the results.

VII. ENERGY AUDIT METHODOLOGY

Energy auditing methodology is divided into the following categories

1) Preliminary energy audit
2) Detailed energy audit.
3) General energy audit

A. *Preliminary Energy Audit*

The preliminary audit alternatively called a simple audit, screening audit or walk-through audit, is the simplest and quickest type of audit. It involves minimal interviews with site operating personnel, a brief review of facility, utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and identify areas of energy wastage, inefficient equipment's. Only major energy consumption areas are uncovered during this type of audit.

B. *Detailed Energy Audit*

Detailed energy is also called comprehensive audit or investment grader audit. It expands on the general energy audit. This covers estimation of energy input for different processes, collection of past data on production levels and specific energy consumption. It is a comprehensive energy audit action plan to be followed effectively by the industry. In detail audit we define energy use and losses through a more detailed review and analysis of equipment, systems, operational characteristics, and on-site measurements and testing.

C. *General Energy Audit*

The general audit alternatively called a mini-audit; site energy audit or complete site energy audit expands on the preliminary audit described above by collecting more detailed information about facility operation and performing a more detailed evaluation of energy conservation measures identified.

The methodology for this audit process given as

1) Data Collection:

In the preliminary data collection phase, exhaustive data collection was performed using different tools such as observation, interviewing key persons, and measurements.

2) Data Analysis:

Detailed analysis of data collected was done using MS-Excel. The database generated by MS-Excel was used for producing graphical representations.

3) Recommendation:

On the basis of results of data analysis and observations, some steps for reducing power consumption without affecting the comfort and satisfaction were recommended along with their cost analysis.

a) Data Collection

For suggesting any corrective measures to reduce power consumption, it is first necessary to know the power consumption pattern in detail. For this, the exhaustive data collection exercise was performed for all the departments, academic center, hostels, and other supporting entities such as library, computer center etc.

Following steps were taken for data collection:

- The team went to each department, administration block, central facilities of institute, hostels etc.
- The power consumption of appliances, rated power was used (for example CFL).
- The details of usage of the appliances were collected by interviewing key persons e.g. caretaker (in case of hostels), lab in-charge (in case of department labs)
- Light intensity has been measured using lux meters at the places having very low and high light intensity.
- In case of Air Conditioned area, room insulation was checked by visual inspection.

Approximations and generalizations were done at places with lack of information.

b) Data Analysis

For data analysis, the data collected is processed to draw significant conclusions to pinpoint loopholes and identify the areas to focus upon. Analysis of the power consumption observations obtained was used to obtain the power consumption pattern and also to get the information of energy wasting areas of the electric power.

c) Recommendation

Energy as well as cost analysis of different appliances were performed and recommendations were made based on the capital cost recovery time.

Following were the steps involved in this process:

- The capital cost involved in replacing an appliance and/or process was estimated. The energy saving by the step was calculated in terms of price of energy per year.
- These two costs were compared to calculate the capital cost recovery time that is defined as the time by which the saving in energy bill, recover the capital cost involved.

If capital cost recovery time is less than the product life, the implementation step can be supported. Some other recommendations were also made which are based on lighting intensity, AC insulation etc.

VIII. ANALYSIS OF POWER CONSUMPTION

Power consumed by equipment, application as well as location analysed and displayed using MS-Excel software. The summary of the analysis presented in the form of bar graph for better understanding.

A. Block/Department Wise

There are ten academic departments i.e. Applied Science (AS), Civil Engineering (CE), Electrical Engineering (EE), Mechanical Engineering (ME), Electronics & Communication Engineering (EC), Computer Science and Engineering (CS), Information Technology (IT), Production Engineering (PE), Business Administration (BA), Computer Applications (CA). There are class rooms (CR), Workshop (WS), Central Library (CL),

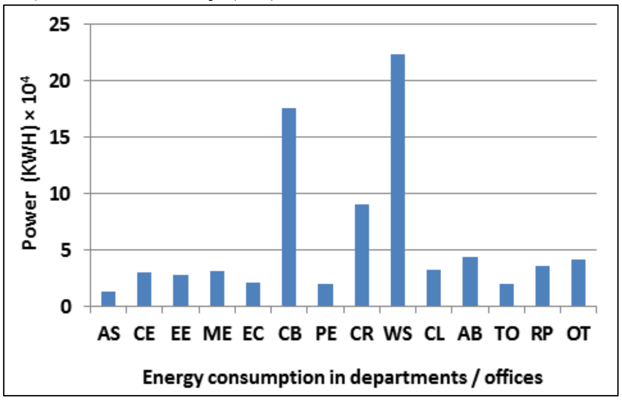

Fig. 1: Power consumed at different locations in college

Administration Block (AB), Trust Office (TO), Refreshment Point (RP) and others (OT) in GNDEC campus. The Computer Science and Engineering, Information Technology, Computer Application and Business Administration departments are in same building. So these departments are calculated jointly. The energy data available for these departments is abbreviated as CB. The analysis of power consumption in the college is shown in Fig 1. It shows the higher consumption of energy in the workshop as compared to other departments

B. Location Wise

The major power consuming areas in campus Laboratories (21%), Class rooms (7%), Offices (4%), Rooms in hostel (37%), Mess (3%), Central facilities (23%) and wash rooms (5%) are important to focus for improving energy efficiency of the campus. It is shown in Fig. 2. Rooms in hostels are the major areas that contribute to energy inefficiency due to poor practices

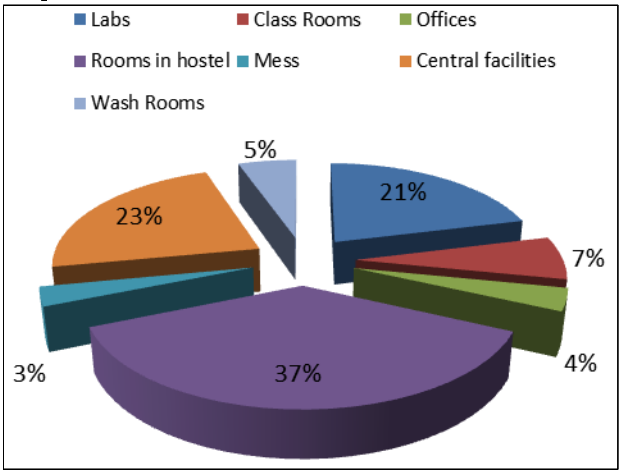

Fig. 2: Location wise consumption of overall campus

C. Equipment Wise

The equipment wise power consumption is shown in Fig. 3. The appliances shown are Old fan (OF), New fan (NF), Wall fan (WF), Tube light (TL), Compact fluorescent lamp (CFL) Personal computers (PC), Air conditioners (AC), Geyser (GE), Refrigerator (RG), Water cooler (WC), Washing machine (WM). Performed the equipment wise analysis to identify the equipment, consuming more power as compared to others within same application area, The equipment with power consumption less than 1% of total power consumption of the campus were ignored to make the analysis results simple and easy.

AC consumes 17% of electrical energy of total power. For lighting purpose the dominant appliance is conventional electric ballast [Choke] tube light with 13% share and relatively efficient electronic ballast [Choke] tube lights and T5 lamps have negligible share. Only the 3% share is consumed by CFL from total power consumption. Computers have a contribution of more than 15% from total power consumption. Fans have 42% share (35% new fans and 7% old fans) and wall fans have negligible share in total power consumption.

Geysers with more than 5% share in total consumption were another significant area in energy saving Water coolers (2%) and refrigerators (1%) and

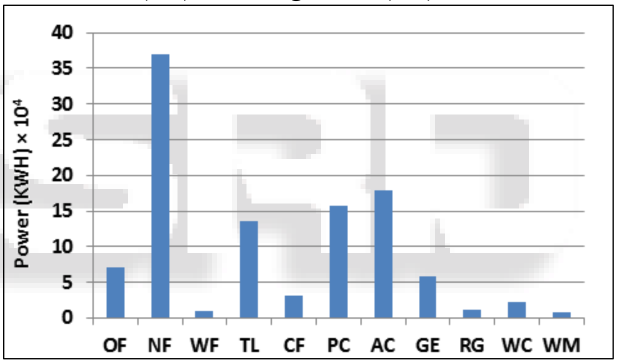

Fig. 3: Equipment wise consumption in campus

washing machine (1%) were also energy consumption appliances with less contribution.

IX. ANALYSIS OF HOSTELS

There are 4 hostels in institute. Three hostels are for boys and one hostel for girls. Each hostel has capacity of 300. Most of the rooms are single seated, but hostel also has four seated in rooms. In single seated rooms, one tube light and one ceiling fan has been provided while in four seated rooms, two tube lights and two ceiling fans are provided. In addition, each hostel has a mess and common room.

Graph shows that Hostel no. 2 and 4 has relatively less power consumption as compared to other hostels. This is due to the less occupancy.

The location wise analysis of all hostels done together suggests that maximum power consumption after rooms is in washroom. This is due to light and geyser is not switched off after use. It is a general complaint of all supervisors that students do not switch off the geyser after the use. In mess, the use of number of other appliances in addition to general appliances in their kitchen consumes more electrical energy.

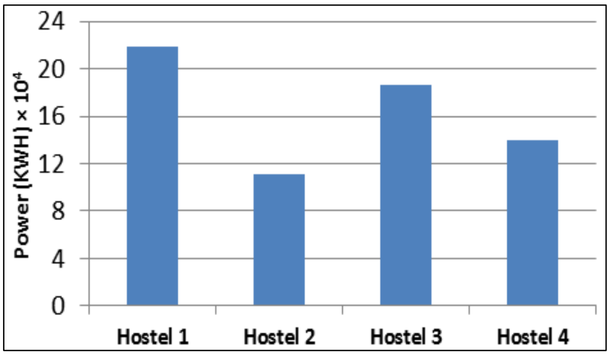

Fig. 4: Power consumption in hostel

The energy consumed in rooms of hostel is 97% of total energy consumption. This area have major role in saving of energy consumption, just by adopting better practices i.e. switch off light or fan not used. Some students don't switch off the lights and/or fans even when they are not in room. Most students keep their computer/laptop in standby mode all the time, electrical power is wasted due to this

Washrooms are the major areas to focus, from energy conservation point of view. Power consumption here can largely be reduced by simply using geyser more wisely. A large potential of saving in energy by using automation in lighting of washrooms, so that the light does not remains switched on all the time. Motion sensors can be utilized to automatically switch off the lights when there is no motion in the corridors.

Fans and Tube lights are maximum power consuming appliances accounts for 59% and 14% of total consumption. Geysers consume 11% of total energy. Consumption in water coolers is 4% of the total power consumption. All other devices have not that much significant consumption.

X. ANALYSIS OF DEPARTMENTS

Institute has ten academic departments. Each department has laboratories, classrooms, faculty rooms, and central facilities.

The maximum power consuming departments are computer science and engineering, information technology, computer application and business administration in Fig. 5. The least power is consumed in the Applied Science department.

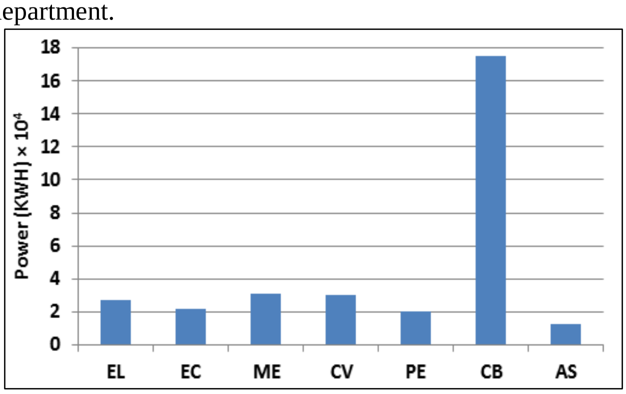

Fig. 5: Power consumption of departments

It is important to mention here that the department of mechanical engineering, electrical engineering, electronics and communication engineering, civil engineering and production engineering include the main administrative block. Computer science and engineering department includes information technology, computer application and business administration department and abbreviated as CB.

Location wise analysis of power consumption in departments points to a surprising fact that in spite of ignoring the special equipment installed in the laboratories and taking into account general appliances,

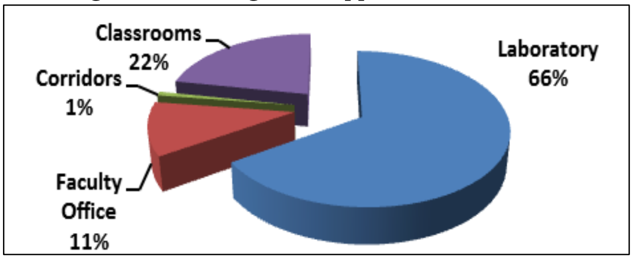

Fig. 6: Location wise consumption in a departments

laboratoraries comprise of nearly half of total power consumption of the departments. The Fig. 6 shows the results of location wise analysis of departments

So, laboratories in a department consume 66% of power consumed in the departments. This is because laboratories are large in number and partly because the appliances are on for the academic duration in a laboratory. Most of the computational labs in a department are air conditioned.

XI. INSTITUTE CENTRAL FACILITIES

The energy audit of following units has been conducted and analyzed under institute central facilities:

1) Administrative Block (AB)
2) Central Library (CL)
3) Workshops (WS)
4) Canteens (CA)
5) Trust Office (TO)
6) Others (OT) includes Gurdwara, Sport complex, Auditorium, Swimming pool, Training & placement cell and Radio station (90.8 FM)

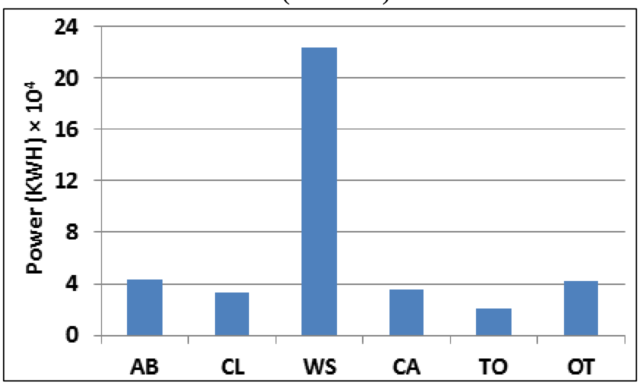

Fig. 7: Power consumption of central facilities

The workshop is the largest power consuming area among the institute central facilities shown in Figure 7. In workshop the machine shop and welding shop consume maximum power. Central library and trust office have very small power consumption as compared to other.

Equipment wise analysis of power consumption in Institute Central Facilities makes the picture clearer. The results summarized in Figure 8.

Large number of appliances whose consumption is less than 1% is ignored to make the analysis simple.

XII. ANALYSIS OF STREET LIGHTS

Sodium Vapour (SV) lamps are dominant lighting source in the streets.

Category	Tube light	S V lamp
Power (W)	40	250
Number	16	26
Hr./day	10	7
Day/Year	365	365
KWH	2336	16607.5
Total Power	18943.5 KWH	

Table 1: Power consumed by street lighting

XIII. BENEFITS AND RECOMMENDATIONS

Based on the analysis of the power consumption data, certain steps have been recommended for improving energy efficiency in the campus. Complete cost analysis of implementation of recommended measures has been performed wherever necessary. Also, a number of general measures for energy efficiency have been listed.

A. Replacing conventional ballast [choke] FTLS with electronic ballast [choke] FTLS:

The light source at most places in the campus is traditional 40W FTLs with conventional Ballast [Choke] which consumes 14-16W. As per data collection, the

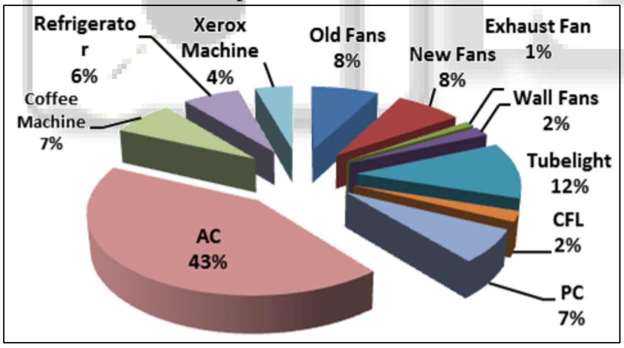

Fig. 8: Consumption of energy in central facilities equipment wise

campus has in total 1912 conventional Ballast [Choke] FTLs and 349 electronic Ballast [Choke] FTLs. If conventional Ballast [Choke] is replaced by electronic Ballast [Choke], 10-12W power per tube can be saved per FTL.
Total conventional Ballast FTLs in campus = 1912
Power consumption of
FTL with conventional Ballast = 56W
FTL with electronic Ballast = 44W
Power saved per FTL = (56 - 44) W =12W
Total Power saving = 1912 × 12W = 22944 W
= 22.944 KW
Average use of FTL per year = 270 days ×7 hr
= 1890 hr/yr
Energy saved per year = 22.944 × 1890 kWh
= 43364.16 kWh
Rate of energy per unit = Rs. 6.55
Saving Rs/year = 43364.16 × 6.55 = Rs. 284035.25
Average Cost of replacing each FTL = Rs. 150
Cost of replacing all FTLs with conventional ballast
= 150 × 1912 = Rs. 286800
Capital Cost Recovery time =286800 / 284035.25
= 1.01 Year

Hence, the recovery time of capital cost for replacing all FTLs with conventional Ballast in the campus is 1 year

B. Replacing old fans with new fans

Most of the buildings in campus are old, and old model fans are still working. From the data collected, there are a total of 503 old fans and 593 new fans. A saving of 40 W per fan can be obtained by replacing the old fans with new ones.

1) Cost Analysis:

Total no. of old fans in campus= 503
Power consumed by old fan= 100 W
Power consumed by new fan= 60 W
Power saved per fan= 40 W
Total Power saving= 503 × 40 = 20120 W = 20.12 kW
Average use of fan per day = 8 hr
Number of days per year working of a fan = 200
Average use of fan per year= 200 × 8 = 1600 hrs
Energy saved per year = 20.12 × 1600 = 32192 kWh
Rate of energy per unit = Rs. 6.55
Saving in Rs/year = 32192 × 6.55 = Rs 210857.6
Average cost of replacing per fan = Rs 1200
Total cost of replacing all the fans = 503 × 1200
= Rs. 603600
Pay back period/Recovery time = 603600/210857.6
= 2.862 years
=2 yr 10 month (approx.)

Hence, the capital cost recovery time for replacing all old fans is approximately 2 year 10 month.

C. Replacing geyser by Solar Water Heating System

Geyser is the device with one of the highest electrical energy consumption in hostels. Heating of water by electricity is the inefficient way. Alternatively, heating water for bathing purpose can be accomplished by solar water heating system (SWHS).

1) Cost Analysis:

Cost of a SWHS = Rs. 17000
Capacity of the SWHS = 100 LPD (litre per day)
Average capacity of geyser = 50 L (litre)
Number of geyser that a SWHS used to replace = 2
Geyser in Hostel 1, 2, 3 and 4 are 6, 6, 16, 6 respectively
Total geyser in hostels = 6 + 6 + 16 + 6 = 34
Average power of geyser = 2 kW
Average use of geyser per day = 5 hr
Number of days per year use of geyser =180
Average use of a per geyser per year = 5 × 180 = 900 h
Number of SWHS required to replace 34 geyser = 17
Cost of 17 SWHS = 17 × 17000 = 289000
Energy saved/year by SWHS = 17×2000×900/1000 kWh
= 30600 kWh
Saving Rs/year = 30600 × 6.55 = Rs. 200430
Capital Cost Recovery time = 289000/200430 = 1.44 yr

Hence, the capital cost recovery time for replacing geysers by SWHS is 1.44 years, i.e.1 year 5 month approximately.

D. Use of motion sensors in corridors and washrooms

Corridors and washrooms have potential of saving energy by the use of automation tools. Motion sensors can be used there to automatically switch on the light as there is movement and switch off the light after fixed time interval. These greatly reduce the power consumption.

1) Cost analysis:

Average power of the tube lights = 40 W
Reduction in 24 hr usage per day by motion sensor = 4h
Energy saved / year = (40×4×365)/1000 = 58.4 kWh
Motion sensors to be installed in Hostel 1, 2, 3 and 4 are 12, 12, 20, 12 respectively.
Total motion sensors = 12 + 12 + 20 + 12 = 56
Energy saving /year = 56 × 58.4 = 3270.4 kWh
Saving in Rs/year = 3270.4 × 6.55 = Rs. 21421.12
Cost of installation per motion sensor = Rs. 250
Total Cost of installing = 56 × 250 = Rs. 14000
Cost Recovery Time = (21421.12/14000) = 1.53 yr

Hence, the capital cost recovery time for installing motion sensors in corridors is 1.53 years i.e 1 year 6 months approximate. Hence, this is a recommended step to reduce the consumption in corridors and washrooms.

E. Better practices for AC

The institute has in total 146 ACs and consumes a large part of energy consumption in the campus. At many places it was observed that AC installation is not used with recommended practices. Even simple things are not taken care, such as insulation. Window panes were found to be broken at many places. Also, at certain places ACs were found to be used without curtains. These practices account for increase in energy consumption.

Given below are guidelines for efficient use of ACs:

1) Proper Insulation:– Good quality insulation must be maintained in the air conditioned rooms by keeping all doors and windows closed so as to prevent hot air come inside the room.
2) Curtains:– Keep curtains on windows to prevent direct sunlight inside the room to avoid heating. This reduces energy consumption of AC significantly.
3) Maintenance:– Proper maintenance and cleaning of ACs is required at regular intervals to make it work at highest efficiency. Dirty filters reduce efficiency of AC.
4) Operating:– The ACs should be switched off 15 minutes before leaving the room.

F. Use of master switch outside each room

Installation of a master switch outside every room can make it easy for a person to switch off all the appliances inside the room, in case someone forgets to switch off while leaving the room. This can help reducing energy.

G. Improved infrastructure

For new hostel to come up, it is advised that CFL/LED lights should be used for lighting and star rated fans. Use of automation i.e. motion sensors in corridors and washrooms to reduce the consumption. Construct Green Buildings and use latest technology for new construction to reduce energy.

Appliance	Number	Annual Savings (KWH)	Annual Savings (Rs.)	Capital Investment (Rs.)	Payback Period (Yrs)
Ballast [Choke]	1912	43364.16	284035.25	286800	1.01
Fan	503	32192	210857.6	603600	2.86
Geysers	34	30600	200430	289000	1.44
Motion Sensor	56	3270.4	21421.12	14000	1.53
Total saving/ year		109426.56	716743.97	1193400	

Table 2: Overall Cost Benefits

XIV. Equipments and Software Used

The data is collected by the use of instruments and analyzed with the help of software used in the project.

A. Digital Lux meter

Digital Lux meter is a device used to measure luminous level in room. Luminous measurements were performed at lecture and laboratory in department.

B. MS-Excel

Datasheets were made in Micro Soft excel software. Thereafter equipment wise analysis, application wise analysis and location wise analysis was performed. This data was then presented in the graphical form.

C. Wattmeter

Wattmeter was used for measuring electric power consumed and to check the ratings of different appliances.

The saving of Rs. 7.16744 lakh per year is computed with the capital investment of Rs 1.1934 lakh. The payback period for this investment is 2.86 years.

XV. Conclusion

Considering the present scenario the wastage of electrical energy is mostly done by user. The installation of new machines and equipment is recommended with low cost, effective and efficient techniques to achieve high efficiency of energy user. The present audit work executed in academic institution. The effective recommendation is presented. The authors recommended the use of renewable energy source. The electricity cost of the institution can be reduced. This energy audit report suggests lesser costly and higher costly investment. Recommendations that can be implemented to save upto Rs. 7.16744 lakh per year with capital investment of 1.1934 lakh rupees. The payback period this investment is 2.86 years.

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